

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to an image forming apparatus which forms an image on a surface of a photosensitive body through an optical scanning device, and, in particular, to an image forming apparatus by which, even employing a device having a low resolution, an apparatus having an apparently high resolution is provided.

2. Description of the Related Art

Recently, improvement in resolution of an image forming apparatus has been demanded as in an LBP (laser beam printer) and so forth.

In order to render high resolution without increasing the printing speed of an LBP, ① the speed of rotation of a deflector such as a polygon scanner may be increased, ② the number of light sources may be increased and thereby scanning is rendered with a plurality of scan lines at once, or the like.

However, ① when the speed of rotation of a deflector such as a polygon scanner is increased, not only the polygon scanner itself becomes expensive, but also the durability thereof becomes degraded, the noise therefrom increases, the power consumption thereof

increases, and so forth.

Further, when ② the number of light sources is increased and thereby scanning is rendered with a plurality of scan lines at once, a configuration for composing a plurality of beams becomes complicated, the number of parts/components increases, thereby costs increasing, and assembling accuracy of the mounted parts/components cannot be maintained because of complexity of the device.

Further, improvement of resolution only in a main scan direction (the same as a deflection direction of a deflector) can be rendered by increasing a modulation frequency of a light source. However, by this method, it is not possible to improve resolution in a sub-scan direction.

As a method of solving the above-mentioned problems, and improving resolution in a main scan direction and also in a sub-scan direction, TrueRes technology is proposed in a document 'technology of improving resolution of page printer - TrueRes Interface Jan./Feb., 1996'. This method has also been put into practice.

The TrueRes technology is to utilize a characteristic in that a toner-adhering amount of toner adhering to a surface of a photosensitive body with

respect to an exposure time for which the photosensitive body is exposed by a beam is determined by an accumulation of the exposure time (exposure distribution).

5 FIG. 1 shows a characteristic of an exposure time and a toner-adhering amount.

 In FIG. 1, in a range in that the exposure time 't' is not longer than t_3 ($t \leq t_3$), a reaction critical value has not been exceeded, and the toner-
10 adhering amount TM is substantially zero.

 In a range in that the exposure time falls between t_3 and t_4 ($t_3 < t < t_4$), the reaction critical value has been exceeded. Then, in a range in that the exposure time t is equal to or longer than t_4 ($t \geq t_4$),
15 the toner-adhering amount TM becomes TM_0 , and is saturated.

 Because the toner-adhering amount is thus determined by accumulation of the exposure time, the toner-adhering amount becomes TM_0 by four times of
20 exposure each rendered for the interval t_1 , and, this is the same as the toner-adhering amount rendered by once of exposure rendered for the interval t_4 .

 Similarly, in a case where exposure is rendered for the interval t_2 , the toner-adhering amount
25 reaches TM_0 by twice of the exposure.

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FIG. 2 shows an image of improving resolution employing the TrueRes technology.

In FIG. 2, G11 through G13 represent dots formed on a scan line L1, G21 through G23 represent dots formed on a scan line L2, and, for each of them, exposure is rendered for an interval equal to or longer than t_4 in the characteristic shown in FIG. 1, and, thereby, the toner-adhering amount is TM_0 .

Further, dots GA formed between adjacent dots can be formed through twice of exposure each rendered for the interval t_2 in the characteristic shown in FIG. 1 on the positions of these adjacent dots, respectively.

For example, a new dot GA can be formed between the dots G11 and G12 on the main scan line L1 in the main scan direction, and another new dot GA can be formed between the dot G11 on the main scan line L1 and the dot G21 on the main scan line L2 in the sub-scan direction.

Thus, by employing the TrueRes technology, it is possible to improve resolution in the main scan direction and also in the sub-scan direction.

Further, in an image forming apparatus in the related art, as disclosed in Japanese Laid-Open Patent Application No. 10-250144 by the present applicant, by employing the TrueRes technology, employing a plurality

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of LED (light emitting diode) arrays in a light source thereof, configuring the respective LED arrays in the main scan direction of a photosensitive body, and controlling turning on/off of each diode, new dots are
5 formed between adjacent normal dots in the main scan direction and in the sub-scan direction.

In the image forming apparatus disclosed in Japanese Laid-Open Patent Application No. 10-250144, the diameters of newly formed dots can be made to
10 approximate those of the normal dots.

In the image forming apparatus disclosed in Japanese Laid-Open Patent Application No. 10-250144 employing the TrueRes technology, resolution of newly formed dots is determined by exposure distribution, and,
15 also, the exposure distribution is mainly determined by a static beam-spot diameter and intervals between scan lines in the sub-scan direction. Accordingly, the resolution is not improved unless the static beam-spot diameter and intervals between scan lines in the sub-
20 scan direction are properly set.

SUMMARY OF THE INVENTION

The present invention has been devised in order to solve such a problem, and an object of the
25 present invention is to provide an image forming

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apparatus in which the static beam-spot diameter and intervals between scan lines in the sub-scan direction are properly set, and, thereby, resolution in the sub-scan direction is improved.

5 Another object of the present invention is to set a condition of improving resolution in the main scan direction.

 According to the present invention,

10 a dot is formed at a center between adjacent light fluxes as a result of the adjacent light fluxes being overlapped with one another in a sub-scan direction, and

 a ratio of a static beam-spot diameter W_s in the sub-scan direction on the surface of a
15 photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot (the diameter of the area of the beam spot through which the exposure intensity is not lower than $1/e^2$ of the maximum value thereof, also hereinafter) to an interval L (in a
20 center-to-center basis, also hereinafter) between adjacent scan lines satisfies the following formula:

$$1.2 < W_s / L < 4.5$$

25 Thereby, it is possible to easily form a dot

at the center between adjacent scan lines, to render shortening of a diameter of each dot and stabilization of the dots and to increase resolution in the sub-scan direction. Accordingly, it is possible to form high-
5 resolution images.

Further, a ratio of a static beam-spot diameter W_m in a main scan direction on the surface of the photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot to
10 the static beam-spot diameter W_s in the sub-scan direction on the surface of the photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot satisfies the following formula:

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$$W_m / W_s < 1$$

Thereby, it is possible to increase resolution in the main scan direction, and to form high-resolution
20 images also high in resolution in the main scan direction.

Other objects and further features of the present invention will become more apparent from the following detailed description when read in conjunction
25 with the accompanying drawings.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a characteristic between exposure time and toner-adhering amount;

FIG. 2 shows an image of increasing resolution
5 by using TrueRes technology;

FIGS. 3A and 3B show a general configuration of an image forming apparatus in each of first through tenth embodiments of the present invention;

FIG. 4 shows an image of forming a new dot for
10 increasing resolution in a sub-scan direction according to the present invention;

FIG. 5 shows conditions of a comparison example and the first through tenth embodiments of the present invention;

FIG. 6 shows a perspective view (bird's-eye
15 view) of exposure distribution in the comparison example;

FIG. 7 shows a perspective view (bird's-eye
view) of exposure distribution in the first embodiment
20 of the present invention;

FIG. 8 shows a perspective view (bird's-eye
view) of exposure distribution in the second embodiment of the present invention;

FIG. 9 shows a perspective view (bird's-eye
25 view) of exposure distribution in the third embodiment

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of the present invention;

FIG. 10 shows a perspective view (bird's-eye view) of exposure distribution in the fourth embodiment of the present invention;

5 FIG. 11 shows a perspective view (bird's-eye view) of exposure distribution in the fifth embodiment of the present invention;

FIG. 12 shows a perspective view (bird's-eye view) of exposure distribution in the sixth embodiment
10 of the present invention;

FIG. 13 shows a perspective view (bird's-eye view) of exposure distribution in the seventh embodiment of the present invention;

FIG. 14 shows a perspective view (bird's-eye
15 view) of exposure distribution in the eighth embodiment of the present invention;

FIG. 15 shows a perspective view (bird's-eye view) of exposure distribution in the ninth embodiment of the present invention;

20 FIG. 16 shows a perspective view (bird's-eye view) of exposure distribution in the tenth embodiment of the present invention;

FIG. 17 shows an exposure distribution of the comparison exmample on a section parallel to a sub-scan
25 direction and passing through a point at which the

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exposure distribution has the maximum value;

FIG. 18 shows an exposure distribution of the first embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 19 shows an exposure distribution of the second embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 20 shows an exposure distribution of the third embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 21 shows an exposure distribution of the fourth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 22 shows an exposure distribution of the fifth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum

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value;

FIG. 23 shows an exposure distribution of the sixth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 24 shows an exposure distribution of the seventh embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 25 shows an exposure distribution of the eighth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value;

FIG. 26 shows an exposure distribution of the ninth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum value; and

FIG. 27 shows an exposure distribution of the tenth embodiment of the present invention on a section parallel to the sub-scan direction and passing through a point at which the exposure distribution has the maximum

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value.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 3A and 3B show a general configuration
5 of an image forming apparatus in each embodiment of the
present invention.

In FIG. 3A, the image forming apparatus 1
includes a control part 2 having a microprocessor as a
base and a memory, and having an operation function and
10 a processing function, and controlling operation of the
entirety of the apparatus, a driving part 3 driving an
optical scanning device 4 based on a control signal and
an image signal provided by the control part 2, the
optical scanning device 4 having a laser diode 4A, a
15 polygon mirror 4B and so fourth, and scanning a
photosensitive body 6 having a photosensitive layer in a
main scan direction thereof by a laser beam reflected by
the polygon mirror 4B, and an image process part 5
provided in a paper passage 13 communicating a paper
20 feeding device 12 containing transfer paper 11, which is
recording media, with a paper ejecting part not shown in
the figure.

The image process part 5 includes the
photosensitive body 6 having a configuration of a
25 photosensitive drum as a main part, and, a charging

The charging device 7 charges a surface of the photosensitive body 6 to one polarity (for example, a minus (-) polarity) uniformly through charging by a roller charging method.

The developing device 8 causes toner having an electric-potential difference with respect to the electrostatic latent image to adhere to the electrostatic latent image formed on the photosensitive body 6. Thereby, the electrostatic latent image is visualized.

The transfer device 9 attracts the thus-visualized toner image from the photosensitive body 6 by an electric-potential difference, and transfers the toner image onto the transfer paper 11.

The cleaning device 10 removes the toner remaining on the photosensitive body 6 after the transfer, by a method of scraping or the like, and, thus, cleans the photosensitive body 6.

5 A fixing device 14 is disposed on the downstream side of the transfer device 9 in the paper passage 13, heats and presses the un-fixed toner adhering to the transfer paper 11 having passed through the transfer device 9, and ,thus, fixes the toner onto
10 the transfer paper 11.

 The control part 2 modulates an image signal through the driving part 3, controls light-emitting intensity or light-emitting time of the laser beam like a pulse according to resolution (for example, 600 dpi.
15 1200 dpi, or the like) of the apparatus emitted from the laser diode 4A, and controls the rotation of the polygon mirror 4B.

 Further, the control part 2 controls the rotation of the drum of the photosensitive body 6, and,
20 when scanning one scan line the surface of the photosensitive body 6 is finished, rotates the drum for a scan-line interval L, so that the laser beam scans a subsequent scan line.

 Further, the control part 2 controls operation
25 and timing of the charging device 7, developing device 8,

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FIG. 4 shows an image of forming new dots for improving resolution in the sub-scan direction.

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The new dot 17 (hatched in the figure) is formed at the position at which the beam spots 15 and 16 overlap with one another in the sub-scan direction between the main scan line 1 and main scan line 2.

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(L/2) in a center-to-center basis are made separate as far as possible for the main scan direction while the part at which two beam spots with the scan-line interval L overlap with one another is utilized for the sub-scan direction.

At this time, it is necessary that the ratio of the static beam-spot diameter W_m in the main scan direction defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot on the surface of the photosensitive body to the static beam-spot diameter W_s in the sub-scan direction defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot on the surface of the photosensitive body satisfies the following formula (2):

$$W_m / W_s < 1 \quad \cdot \cdot \cdot (2)$$

When W_m / W_s in the formula (2) is not smaller than the upper limit 1, the beam-spot diameter W_m in the main scan direction is too large with respect to the dot interval in the main scan direction, and, thereby, dots are thickened, and/or, unstable. Accordingly, it is not possible to render high resolution.

Reasons why the above-mentioned formulas (1) and (2) are reasonable will now be described based on a

comparison example and the embodiments of the present invention.

FIG. 5 shows conditions of the comparison example and embodiments of the present invention.

5 In each of the comparison example and embodiments 1 through 10, a new dot formed in the sub-scan direction is formed from overlapping, with one another, two beam spots on main scan lines adjacent in the sub-scan direction with the scan-line interval of L .

10 Further, the beam spot moves in the main scan direction while the light source (laser light) is turned on, and each moving distance is assumed to be $1/4$ of the scan-line interval L ($L/4$).

15 Further, the shape of a static beam spot is assumed to be of an ideal Gaussian distribution.

Further, each of W_m and W_s is a diameter of a beam spot in a stationary state defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot.

20 FIGS. 6 through 16 show perspective views of the exposure distributions in intensity of the comparison example and 1 through 10 embodiments of the present invention, and FIGS. 17 through 27 show the exposure distributions in intensity each on a section
25 passing through the point at which the exposure

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distribution has the maximum value in intensity and in parallel to the sub-scan direction.

In each figure, the intensity of exposure distribution is normalized so that the maximum value is 100, and, it is assumed that, when the exposure intensity exceeds 50% of the maximum value, a new dot is formed there.

In the comparison example shown in FIGS. 6 and 17, two dots are separate, and the exposure intensity at the center between adjacent scan lines is far smaller than 50% of the maximum value. Accordingly, no new dot cannot be formed there.

In this comparison example, $W_s / L = 1$, and, thus, the condition of the formula (1) is not satisfied.

In each of the embodiment 1 shown in FIGS. 7 and 18, and the embodiment 6 shown in FIGS. 12 and 23, there is no peak at the center between adjacent scan lines. However, the exposure intensity at the center exceeds 50% of the maximum value. Accordingly, a new dot can be formed at the center.

In each of the embodiments 1 and 6, $W_s / L = 1.21$. Thus, this value is very near to the lower limit 1 of the formula (1).

As described above, when the exposure intensity exceeds 50% of the maximum value at the center

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between adjacent scan lines, a new dot can easily be formed at the center between the adjacent scan lines, and, W_s / L is equal to the lower limit value 1 when the exposure intensity at the center of the adjacent scan lines is 50% of the maximum value.

In each of the embodiment 5 shown in FIGS. 11 and 22 and the embodiment 7 shown in FIGS. 13 and 24, $W_s / L = 1.40$, and there is no peak at the center between adjacent scan lines. However, the exposure intensity at the center exceeds 50% of the maximum value, and, also, is higher than those in the embodiments 1 and 6. Accordingly, a new dot can be formed at the center more positively.

In each of the embodiment 2 shown in FIGS. 8 and 19 and the embodiment 8 shown in FIGS. 14 and 25, $W_s / L = 1.81$. Accordingly, a new dot can be formed at the center between adjacent scan lines far more positively.

In each of the embodiment 3 shown in FIGS. 9 and 20, the embodiment 4 shown in FIGS. 10 and 21, the embodiment 9 shown in FIGS. 15 and 26 and the embodiment 10 shown in FIGS. 16 and 27, $2.5 < W_s / L < 4.5$. Accordingly, the exposure distribution has a peak at the center between adjacent scan lines. Accordingly, a new dot can be formed at the center between adjacent scan lines easily.

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However, when W_s / L becomes equal to or higher than the upper limit (4.5) of the formula (1), the static beam-spot diameter in the sub-scan direction with respect to the scan-line interval L is too large, and, thereby, the new dot is too large, and/or is unstable. Accordingly, it is not possible to render high resolution.

When considering to render formation of a dot at the center between adjacent two scan lines and shortening of diameter of each image dot and stability of the image dots, it is preferable that the ratio of the static beam-spot diameter W_s in the sub-scan direction on the surface of the photosensitive body defined by $1/e^2$ of the maximum value in the exposure distribution of the beam spot to the scan-line interval L satisfies the following formula (3):

$$1.8 < W_s / L < 3.5 \quad \cdot \cdot \cdot (3)$$

Further, as shown in FIG. 5, each of the embodiments 1 through 10 satisfies the condition of the above-mentioned formula (2), and it is possible to render high resolution also in the main scan direction. However, it is preferable that the ratio of W_m to W_s satisfies the following formula:

incorporated by reference.

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